Cell: The Unit of Life - Part 3

Objective

After going through this lesson, the learners will be able to:

- Describe the structure and function of cell membrane
- Explain the difference between cell wall and cell membrane
- Differentiate between Gram Positive & Gram Negative Bacteria
- Enumerate the different cell organelles and their specific functions

Content Outline

- Introduction
- Cell Membrane & Cell Wall
- Cell Organelles - An Overview
- Endomembrane System (Endoplasmic Reticulum)

Introduction

Cell is the basic structural and functional unit of a living organism. Cells are of different shapes and sizes and perform varied functions. In the previous module, we discussed the categorisation of cells into animal cells, plant cells, prokaryotic and eukaryotic cells depending upon their cellular structure. In this module we shall discuss the anatomical structures and the endomembrane system of the cells comprising various sub-components of cells that are called as 'Cell Organelles'.

Cell Membrane

Cell Membrane or the Plasma Membrane refers to the membranous covering of the protoplast or cell protoplasm. The membrane is composed of lipoprotein with oligosaccharides on the outer surface. It is protective in nature and is only selectively permeable. There are a number of receptor sites, attaching sites, recognition sites and antigens on the surface of the plasma membrane. The following figure depicts the detailed structure of a plasma membrane. The structure of the cell membrane as depicted in the figure is composed of a phospholipid bilayer, interspersed by alpha-helix proteins. This structure of the plasma membrane was proposed by Singer & Nicolson (1972), as the 'Fluid Mosaic Model', wherein a lipid bilayer is interspersed by Proteins.

The ratio of protein and lipid varies considerably in different cell types. In human beings, the membrane of the erythrocyte has approximately 52 percent protein and 40 per cent lipids. Depending on the ease of extraction, membrane proteins can be classified as integral or peripheral. Peripheral proteins lie on the surface of the membrane while the integral proteins are partially or totally buried in the membrane.

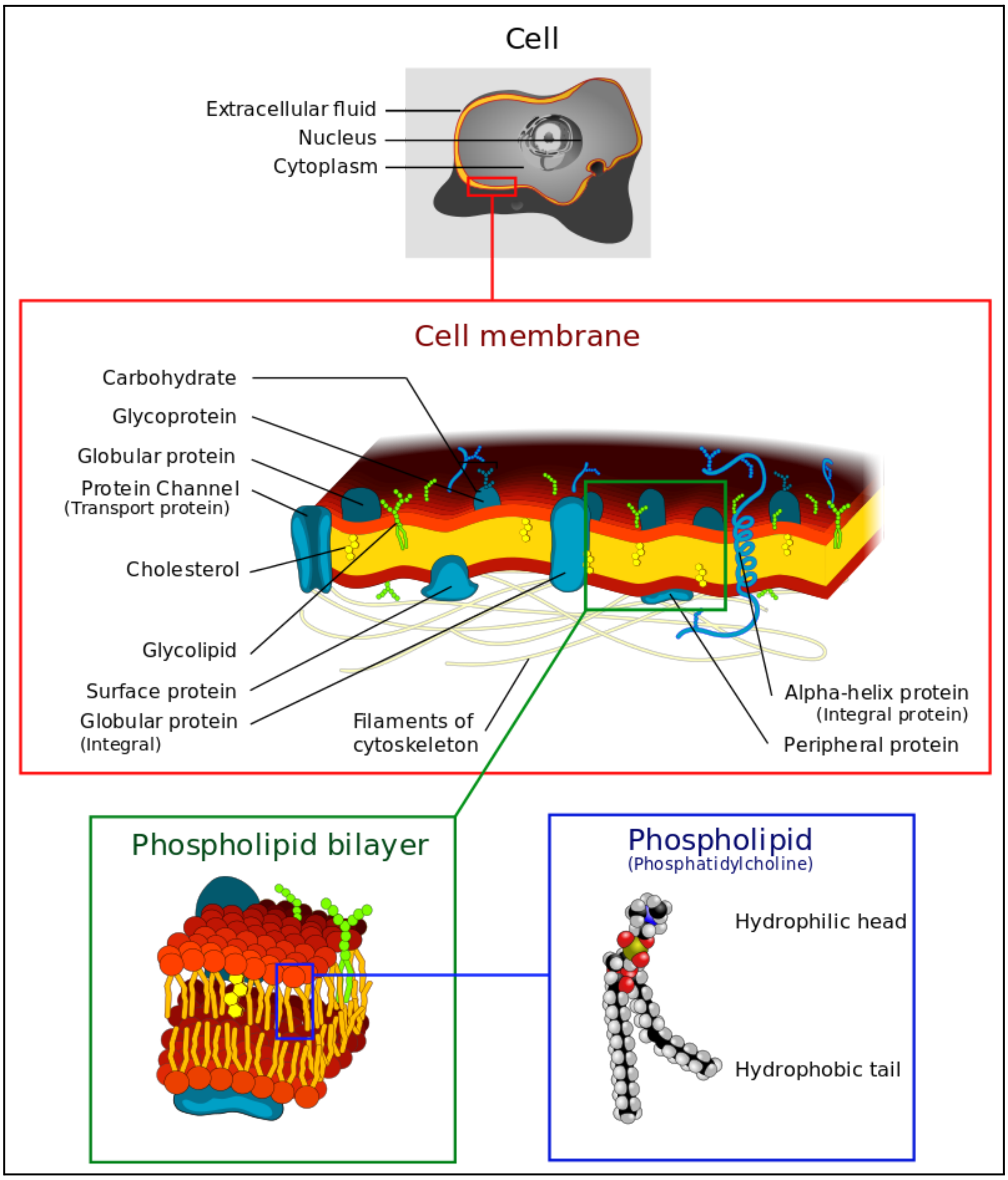

Figure: Illustration of a Eukaryotic Cell Membrane

Transport across Plasma Membrane

One of the most important functions of the plasma membrane is the transport of the molecules across it. The membrane is selectively permeable to some molecules present on either side of it. Many molecules can move briefly across the membrane without any requirement of energy and this is called the **passive transport**. Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient, i.e., from higher concentration to the lower. Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion is called **osmosis**. As the polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane. A few ions or molecules are transported across the membrane against their concentration gradient, i.e., from lower to the higher concentration. Such a transport is an energy dependent process, in which ATP is utilised and is called **active transport**, e.g., Na+/K+ Pump.

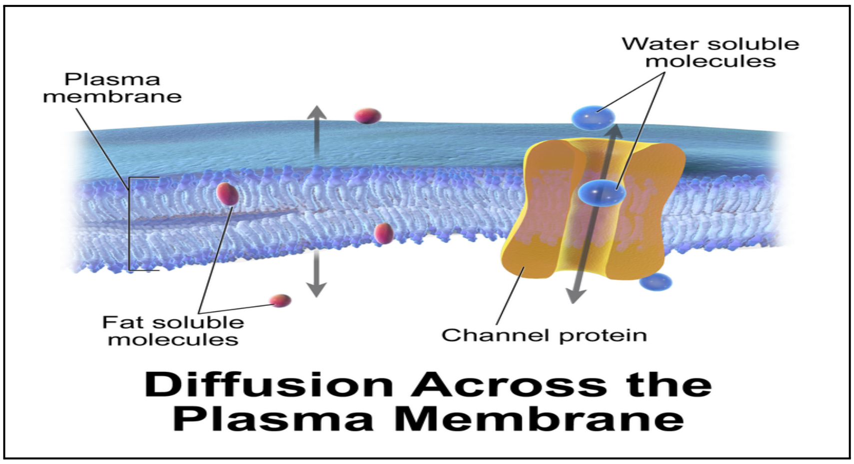

Figure: Illustration depicting Cellular Diffusion (Passive Transport)

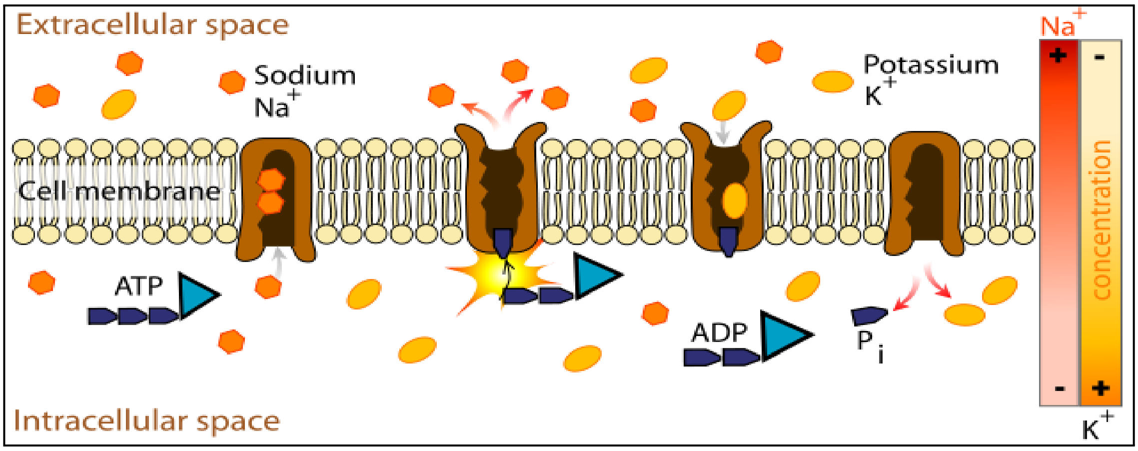

Figure: Action of Sodium-Potassium Pump (Active Transport)

Table: Difference between Active Transport & Passive Transport

S.No.	Active Transport	Passive Transport
1.	It involves the expenditure of energy by the cell.	Energy is not spent in passive transport.
2.	It usually occurs against the concentration or electrochemical gradient.	It always occurs along the concentration gradient.
3.	It helps in the accumulation of substances in the cells.	It does not allow accumulation of substances in the cell unless they are immobilised or utilised.
4.	Active Transport is a vital process	It is a physical process.
5.	It is unidirectional	It is bidirectional.
6.	It is reduced or stopped with the decrease in oxygen content or temperature.	Passive transport is not affected by any of these.

Gram Positive and Gram Negative Bacteria

In prokaryotic cells, the cell is bounded by a complex three-layered envelope, comprising of outermost layer called 'Glycocalyx', followed by the 'cell wall' and the plasma membrane. All these layers help in protection of the cell. Based on the differential response to the 'Gram' Stain, the Bacteria can be classified as 'Gram Positive' and 'Gram Negative' Bacteria.

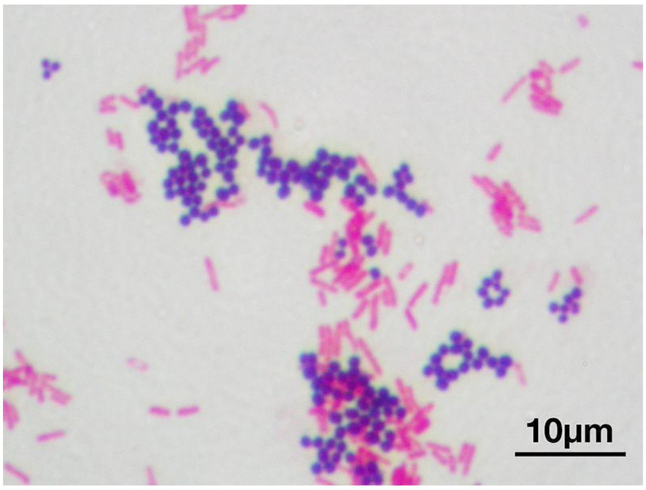

Figure: Microscopic image of a Gram stain of mixed Gram-positive cocci (*Staphylococcus aureus* ATCC 25923, purple) and Gram-negative bacilli (*Escherichia coli* ATCC 11775, red).

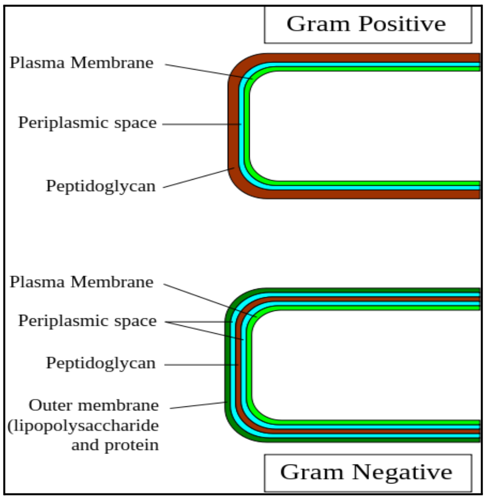

Figure: Differences between Gram-positive and gram-negative bacteria

Other Membranous Structures in Prokaryotes

Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the **slime layer** in some, while in others it may be thick and tough, called the **capsule**. The **cell wall** determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing. The plasma membrane is semi-permeable in nature and interacts with the outside world. This membrane is similar structurally to that of the eukaryotes. A special membranous structure is the **mesosome** which is formed by the extensions of plasma membrane into the cell. These extensions are in the **form of vesicles, tubules and lamellae**. Their functions include:

- Cell wall formation,
- DNA replication and distribution to daughter cells,
- Respiration,
- Secretion processes,
- Increase the surface area of the plasma membrane and enzymatic content.
- In prokaryotes like cyanobacteria, there are other membranous extensions into the cytoplasm called chromatophores which contain pigments.

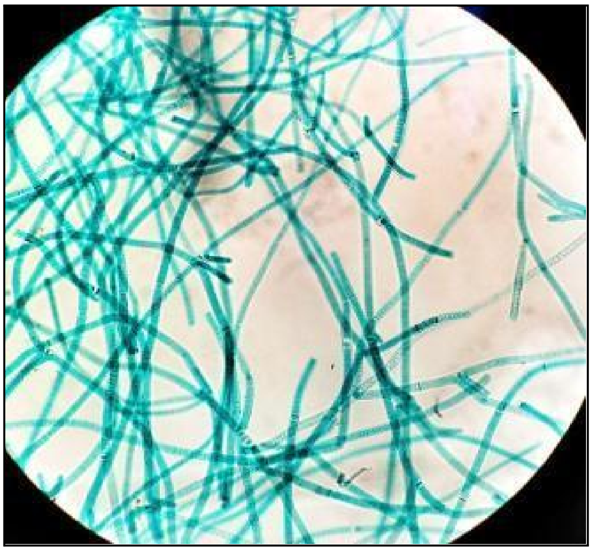

Figure: Cyanobacteria with Pigment

Bacterial cells may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called **flagella**. Bacteria show a range in the number and arrangement of flagella. Bacterial flagellum is composed of three parts – filament, hook and basal body. The filament is the longest portion and extends from the cell surface to the outside. Besides flagella, **Pili** and **Fimbriae** are also surface structures of the bacteria but do not play a role in motility. The pili are elongated tubular structures made of a special protein. The fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

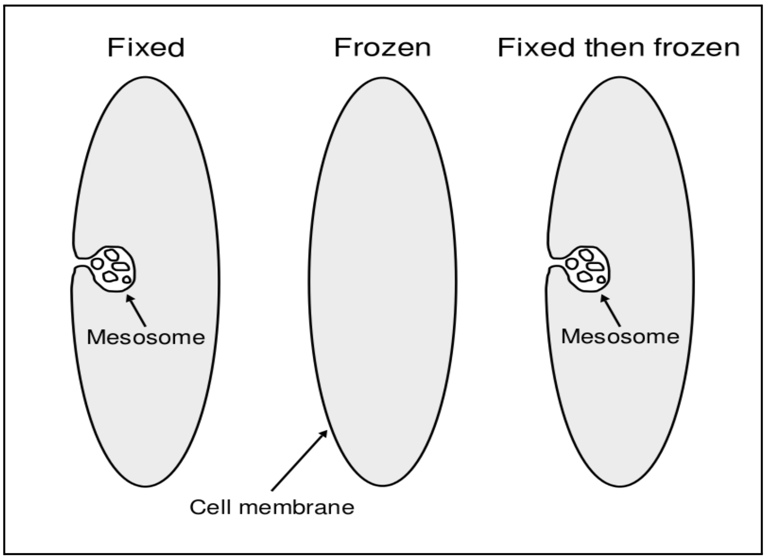

Figure: Mesosomes in Bacterial Cells

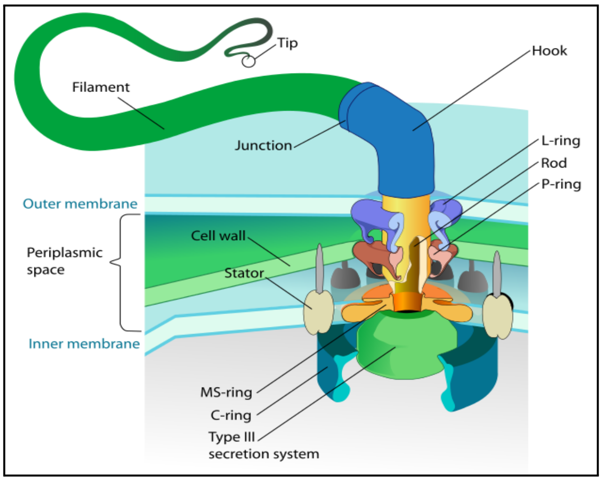

Figure: A Gram-negative bacterial flagellum

Cell Wall

Cell wall is a rigid outer structure that provides shape and strength to the cell and protects the cell against any kind of stress, mechanical damage or foreign elements. It also helps in cell to cell interaction and management of materials inside & outside the cell. Cell wall is made up of cellulose, galactans, mannans and minerals like calcium carbonate, while in other plants it consists of cellulose, hemicellulose, pectins and proteins. The cell wall of a young plant cell, the **primary wall** is capable of growth, which gradually diminishes as the cell matures and the secondary wall is formed on the inner (towards membrane) side of the cell.

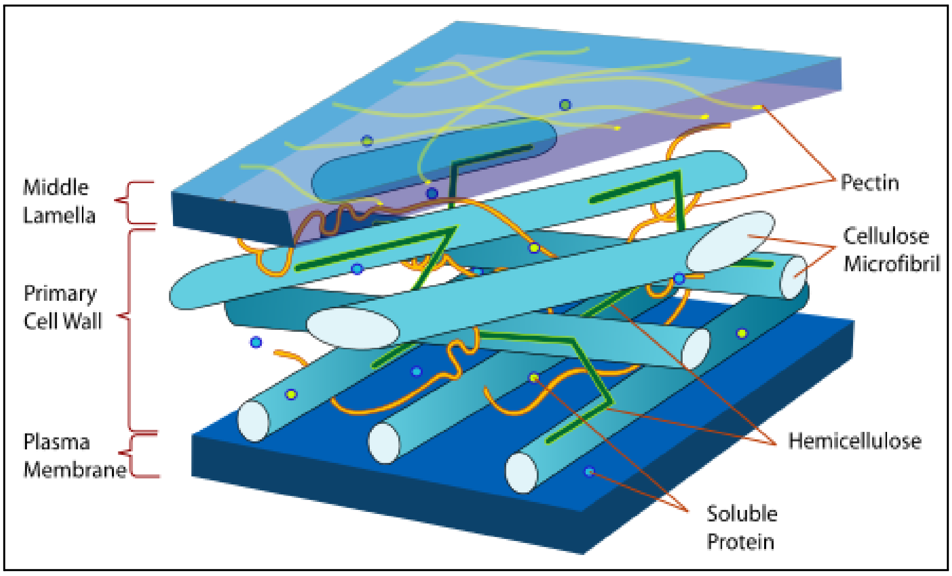

Figure: A section of the Plant Cell Wall

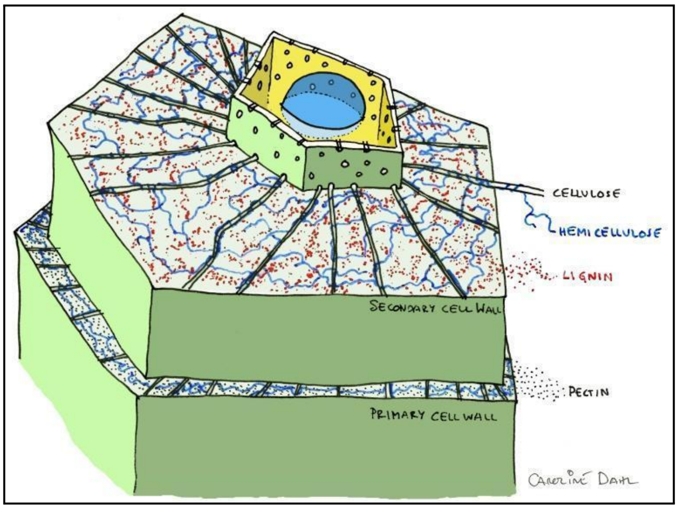

Figure: Plant Cell showing primary & secondary wall

Difference between Cell Membrane and Cell Wall

Cell wall and cell membrane are protective sheaths around a cell, however there are certain differences in their structures and functions. These can be taken as follows.

S.No.	Cell Membrane	Cell Wall
1.	cell membrane is also known as the plasma membrane or plasma lemma.	Cell wall is the outermost covering of the cell. The cell wall covers the cell membrane.
2.	Cell membrane is present in almost all types of cells.	cell wall is present in bacteria, fungi, algae and plant cell. It is absent in an animal cell and protozoa.
3.	Cell membrane is a biological membrane, which is semi- permeable. It allows the passage of certain substances through them.	The function of the cell wall varies in different cells. In multicellular organism, it is responsible for its morphology. It prevents only large molecules from entering the cell and thereby, prevents toxicity to the cell.
4.	It separates the components inside the cell from the outside. The cell membrane provides support to the cytoskeleton of	The function of the cell wall is to provide strength and rigidity to the cell. It protects the cell against mechanical

	the cell, gives shape to the cell, and helps in the formation of tissues by attaching the matrix found in the extracellular.	forces.
5.	The cell membrane is made up of proteins, carbohydrates and lipids. Three types of lipids are found, viz., glycolipids, phospholipids and steroids.	The composition of the cell wall varies in prokaryotic and eukaryotic cells. In prokaryotes, the cell wall is made up of peptidoglycans in the inner layer and lipoproteins, lipopolysaccharides in the outer layer. In eukaryotes, the primary cell wall is made up of cellulose, middle lamella is made up of pectins which are polysaccharides and secondary cell wall is made up of cellulose and lignin.
6.	Plasma membrane is not elastic, but permeable.	The cell wall is elastic and controls turgidity.

Cell Organelles

Cell organelles are also referred to as subcellular structures having characteristic morphological forms and distinctive functions which can be carried out by them even outside the cell cytoplasm provided they are supplied with substances that are normally present inside the cell. The various cell organelles found in the cell include mitochondria, plastids, endoplasmic reticulum, Golgi complex, lysosomes, etc. Let us discover about each of these cell organelles in detail along with their specific structures and functions.

Endoplasmic Reticulum

The highly convoluted and labyrinthine structure of the ER led to its description in 1945 as a "lace-like reticulum" by cell biologists Keith Porter, Albert Claude, and Ernest Fullman, who produced the first electron micrograph of a cell. In the late 1940s and early 1950s, Porter and colleagues Helen P. Thompson and Frances Kallman introduced the term *endoplasmic reticulum* to describe the organelle. Porter later worked with Romanian-born American cell biologist George E. Palade to elucidate key characteristics of the ER.

All eukaryotic cells contain an endoplasmic reticulum (ER). In animal cells, the ER usually constitutes more than half of the membranous content of the cell. Electron microscopic studies of eukaryotic cells reveal the presence of a network or reticulum of tiny tubular structures scattered in the cytoplasm that is called the endoplasmic reticulum (ER) (Figure 8.5). Hence, ER divides the intracellular space into two distinct compartments, i.e., luminal (inside ER) and extra luminal (cytoplasm) compartments. The ER often shows ribosomes attached to their outer surface. The endoplasmic reticulum bearing ribosomes on their surface is called rough endoplasmic reticulum (RER). In the absence of ribosomes they appear smooth and are called smooth endoplasmic reticulum (SER). RER is frequently observed in the cells actively involved in protein synthesis and secretion. They are extensive and continuous with the outer membrane of the nucleus. The smooth endoplasmic reticulum is the major site for synthesis of lipid. In animal cells lipid-like steroidal hormones are synthesised in SER.

Figure: A scanning electron micrograph of a pancreatic acinar cell, showing mitochondria (blue), rough endoplasmic reticulum (yellow; ribosomes appear as small dots), and Golgi apparatus (gray, at centre and lower left).

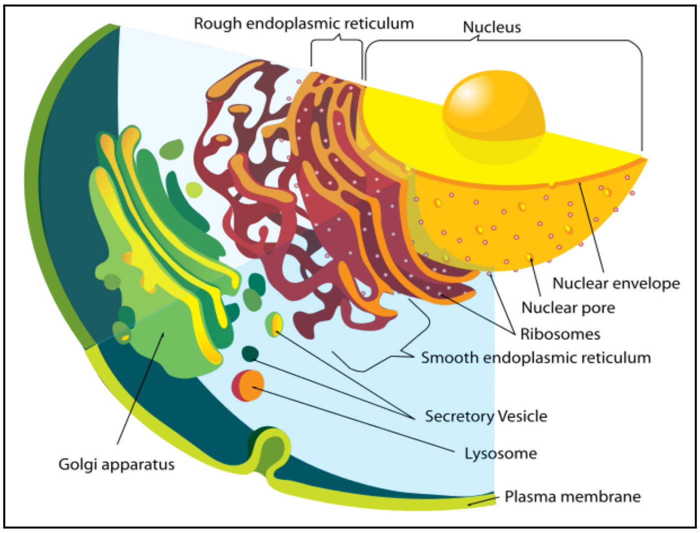

Figure: Details of Endomembrane System & its components

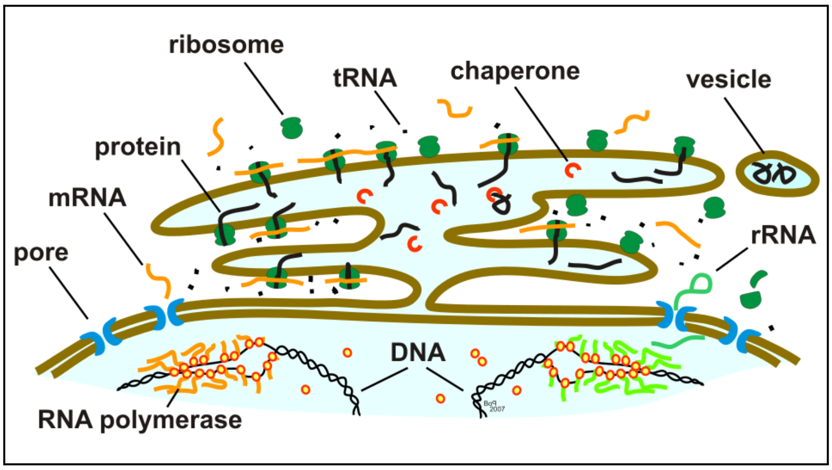

Figure: Protein Synthesis in Endoplasmic Reticulum

The ER is the compartment where newly-synthesized polypeptides fold, where many multimeric proteins assemble and where glycoproteins acquire their asparagine-linked glycans. The ER also provides a protein quality control function and proteins are usually retained in this compartment until they have acquired their correct conformation. The proximity of the rough ER to the cell nucleus gives the ER unique control over protein processing. The rough ER is able to rapidly send signals to the nucleus when problems in protein synthesis and folding occur and thereby influences the overall rate of protein translation. When misfolded or unfolded proteins accumulate in the ER lumen, a signaling mechanism known as the unfolded protein response (UPR) is activated. The response is adaptive, such that UPR activation triggers reductions in protein synthesis and enhancements in ER protein-folding capacity and ER-associated protein degradation. If the adaptive response fails, cells are directed to undergo apoptosis (programmed cell death).

Smooth ER, by contrast, is not associated with ribosomes, and its functions differ. The smooth ER is involved in the synthesis of lipids, including cholesterol and phospholipids, which are used in the production of new cellular membrane. In certain cell types, smooth ER plays an important role in the synthesis of steroid hormones from cholesterol. In cells of the liver, it contributes to the detoxification of drugs and harmful chemicals. The sarcoplasmic reticulum is a specialized type of smooth ER that regulates the calcium ion concentration in the cytoplasm of striated muscle cells.

Table: Difference between RER & SER

S.No.	Rough Endoplasmic Reticulum (RER)	Smooth Endoplasmic Reticulum (SER)
1.	It possesses ribosomes attached to its membranes.	It does not bear ribosomes.
2.	It is mainly formed of cisternae & a few tubules.	It is mainly formed of vesicles & tubules.
3.	The reticulum takes part in the synthesis of proteins & enzymes.	It is engaged in the synthesis of glycogen, lipids & steroids.
4.	It helps in the formation of Lysosomes through the agency of Golgi apparatus.	SER gives rise to sphaerosomes.
5.	RER possesses pores for the passage of proteins into ER channels.	Pores are absent in SER.
6.	It is internal and connected with a nuclear envelope.	It is peripheral and may be connected with plasmalemma.